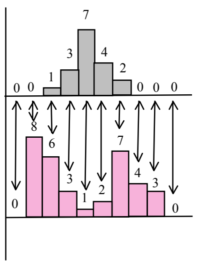
Sensor/light interaction example

R=(0,0,1,3,7,4,2,0,0,0)

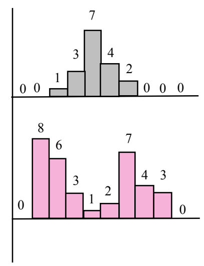


L=(0,8,6,3,1,2,7,4,3,0)

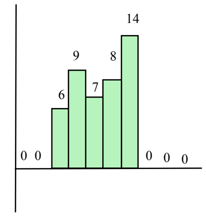
Multiply lined up pairs of numbers and then sum up

Sensor/light interaction example

R=(0,0,1,3,7,4,2,0,0,0)



L=(0,8,6,3,1,2,7,4,3,0)



L .* R=
(0*0, 0*8, 1*6, 3*3, 7*1, 4*2, 2*7, 0*4, 0*3, 0*0)
= (0, 0, 6, 9, 7, 8, 14, 0, 0, 0)

L • P = 0 + 0 + 6 + 9 + 7 + 8 + 14
= 44

Image Formation (Spectral)

- Note that by this model, light capture is linear.
- Formally this means:

$$L_1(\lambda) -> r_1^{(k)} \text{ and } L_2(\lambda) -> r_2^{(k)}$$

- Then:

$$aL_1(\lambda) + bL_2(\lambda) -> ar_1^{(k)} + br_2^{(k)}$$

Image Formation (Spectral)

- Note that image formation loses spectral information
- This means that two quite different spectra can map into the same color

One tricky bit

Electronic capture (e.g. “CCD”) is linear, but typically the circuitry will put the sensor responses through a non-linear mapping (e.g. approximate square root).

This is because display is usually either non-linear due to physics (CRT) or by design (to be like a CRT). This is better because there is less relative noise where humans will notice it.

(A bit more on this later).

Causes of color

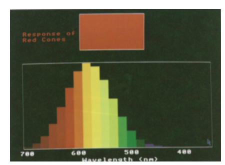
- The sensation of color is caused by the brain.
- One way to get it is through a **response** of the eye to the presence/absence of light at various wavelengths.
- Dreaming, hallucination, etc.
- Pressure on the eyelids

Trichromaticity

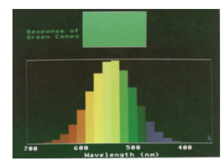
Empirical fact--colors can be approximately described/matched by three quantities (assuming normal color vision).

Need to reconcile this observation with the spectral characterization of light

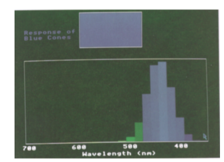
Color receptors



“Long” cone



“Medium” cone



“Short” cone

Some understanding results from an analogy with camera sensors

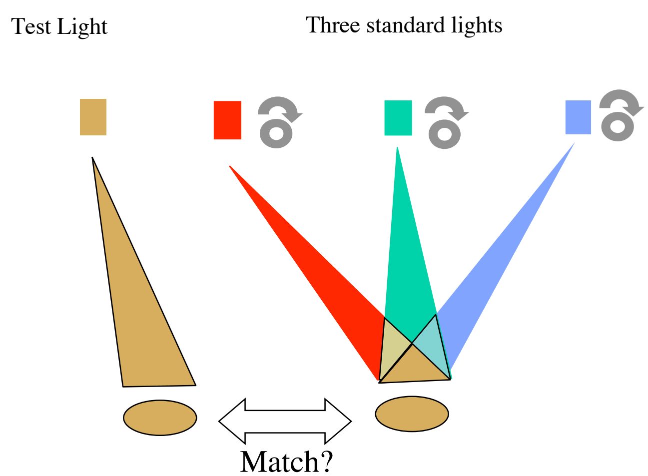
Directly determining the camera like sensitivity response is hard!

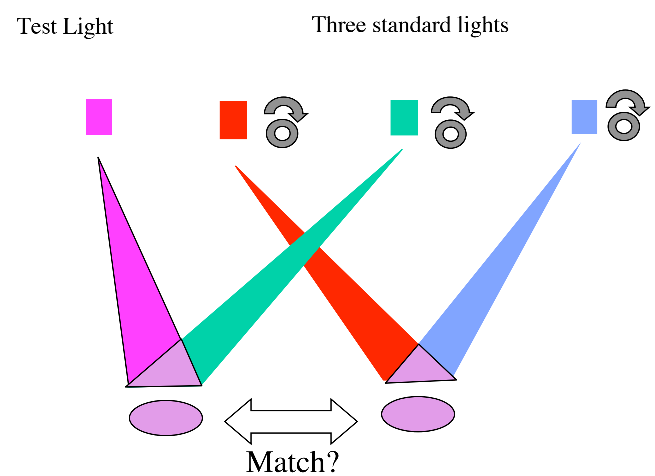
Colour Reproduction

Motivates specifying color numerically (there are other reasons to do this also)

General (man in the street) observation--color reproduction *sort of* works.

Specifying Colour





Trichromacy

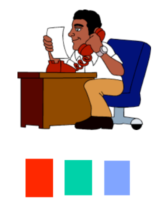
Experimental fact about people (with “normal” colour vision)---matching works (for reasonable lights), provided that we are sometimes allowed negative values.

Our “knob” positions correspond to (X,Y,Z) in the standard colorimetry system.

Technical detail: (X,Y,Z) are actually arranged to be **positive** by a linear transformation, but these “knob” positions **cannot** correspond to any **physical** light.

Specifying Colour

(50,150,75)



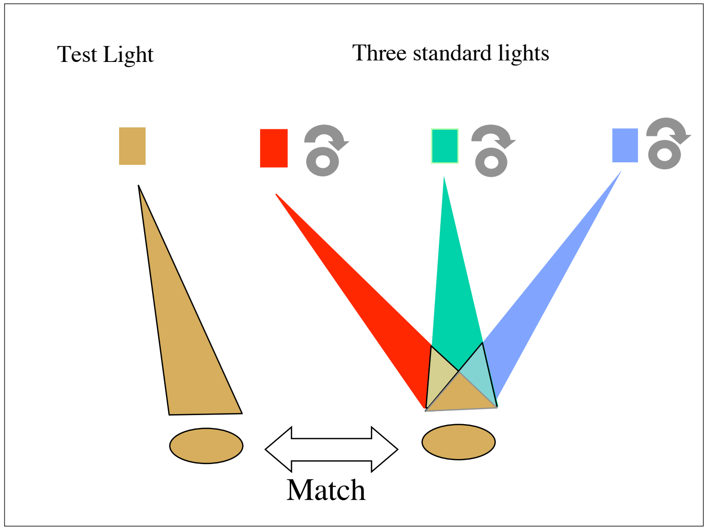
(50,150,75)

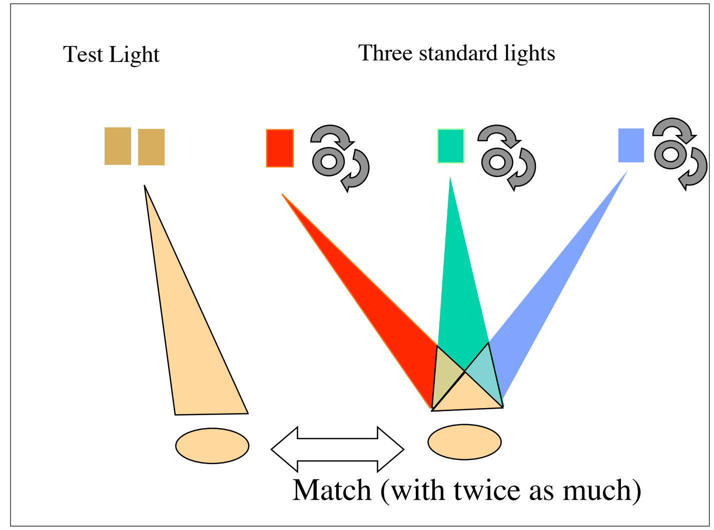
Specifying Colour

We don’t want to do a matching experiment every time we want to use a new color!

Grassman’s Contribution

Colour matching is linear



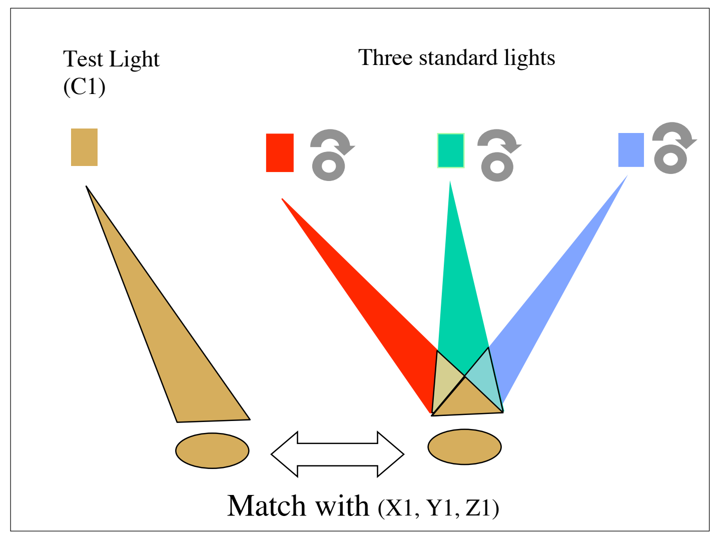


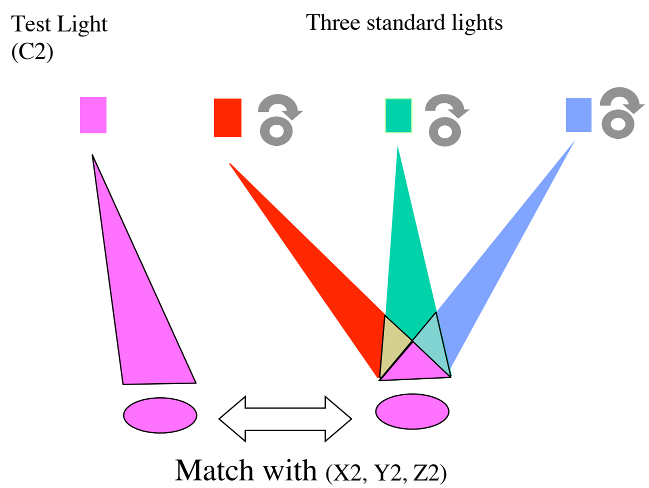
Matching is Linear (Part 1)

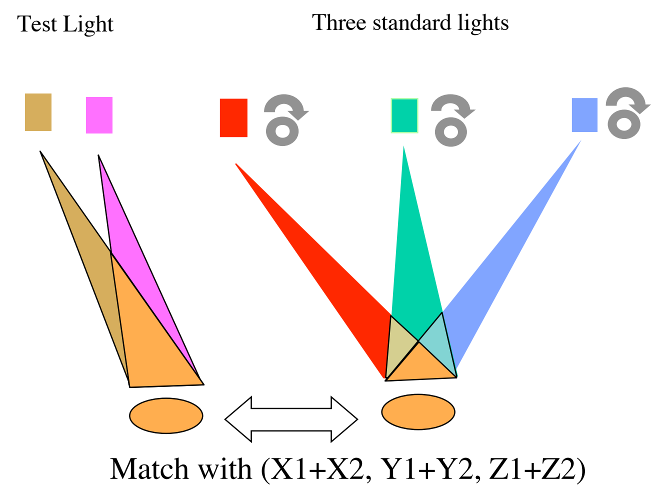
C1 is matched with (X1,Y1,Z1)

C = a*C1

C is matched with a * (X1, Y1, Z1)







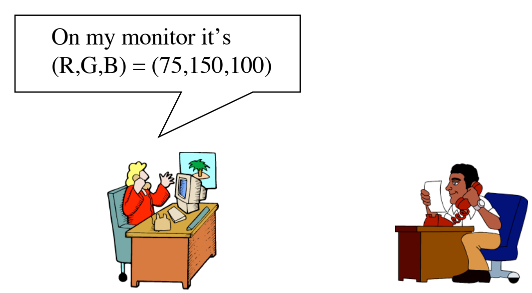
Matching is Linear (formal)

C = a*C1 + b*C2

C1 is matched with (X1,Y1,Z1)
C2 is matched with (X2,Y2,Z2)

C is matched by
a*(X1,Y1,Z1) + b*(X2,Y2,Z2)

Specifying Color



Specifying Colour

But what is (R,G,B)?

Specifying Colour

R matches (X_r, Y_r, Z_r)

G matches (X_g, Y_g, Z_g)

B matches (X_b, Y_b, Z_b)

Specifying Colour

Then by (R,G,B)=(75,150,100) you mean (X,Y,Z), where …..

$$X = 75^* X_r + 150^* X_g + 100^* X_b$$

$$Y = 75^* Y_r + 150^* Y_g + 100^* Y_b$$

$$Z = 75^* Z_r + 150^* Z_g + 100^* Z_b$$

(No need to match--just compute!)

Specifying Colour

… , now that we have specified the colour, I can print it!

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = \begin{vmatrix} X_r & X_g & X_b \\ Y_r & Y_g & Y_b \\ Z_r & Z_g & Z_b \end{vmatrix} \begin{vmatrix} 75 \\ 100 \\ 150 \end{vmatrix}$$

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = \begin{vmatrix} X_r & X_g & X_b \\ Y_r & Y_g & Y_b \\ Z_r & Z_g & Z_b \end{vmatrix} \begin{vmatrix} R \\ G \\ B \end{vmatrix}$$

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = M \begin{vmatrix} R \\ G \\ B \end{vmatrix}$$